NDIA

Architecture Analysis for System-of-System (SoS) Interoperability Assessment

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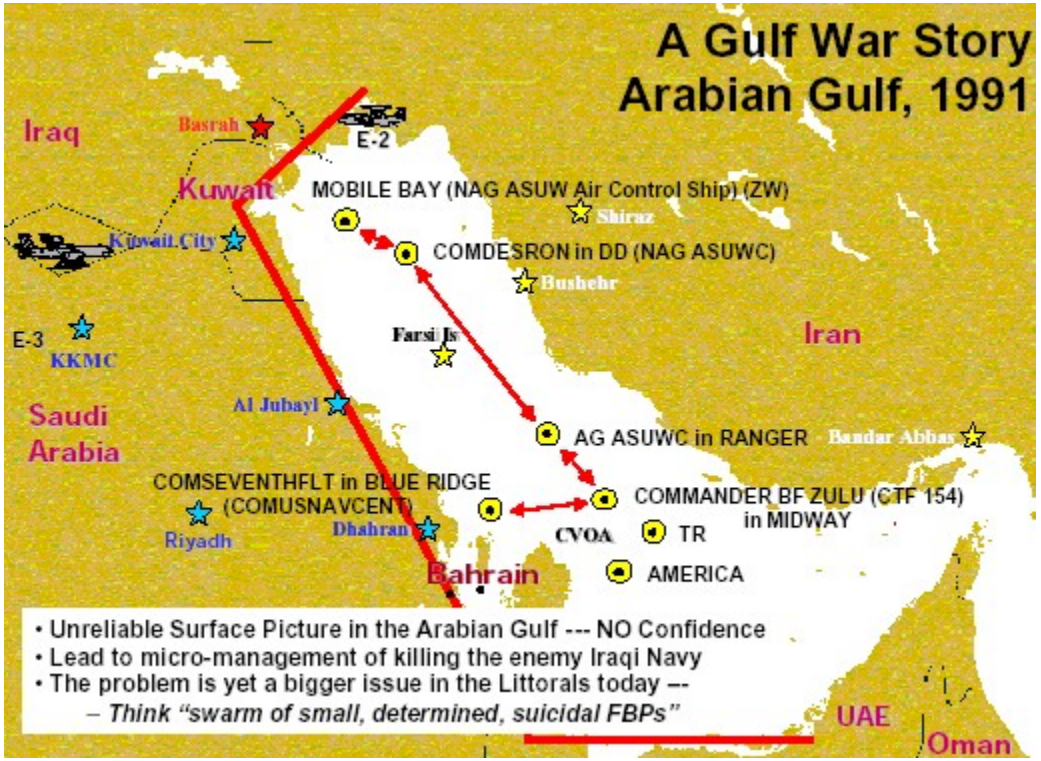
Executive Summary

- **Describe the interoperability problem space**
- **Introduce architecture analysis**
- **Provide an example Architectural Development Process that is segmented according to use, and**
- **Illustrate the approach for addressing the System-of-System Collaboration/Interoperability.**
- **Touch briefly on architectural futures critical for reaching interoperability goals**

System-of-system Interoperability Goals

- **Interoperability sought is the shared understanding necessary for**
  - **A set of heterogeneous autonomous warfighting systems**
  - **To cooperate as a federation of systems**
  - **To provide operational capability greater than the sum of the capability of the individual systems.**
- **Interoperability improves the forces capability to**
  - **Plan effectively**
  - **Control the battlespace**
  - **Conduct precision engagements**



Interoperability Shortcomings

Battle Force Interoperability Shortcomings Addressed by PLP *	
1. Common Time Reference	+++++
2. Navigation	+++++
3. Sensor Information Processing	+++
4. Connectivity	+++++
5. Data Registration	+++++
6. Correlation	+++
7. Combat Identification	+++++
8. HMI	+++
9. Distributed Weapons Coordination	+++
10. Taxonomies	+++++
11. Data Resolution	+++
12. Communication Topology	+++++

Shortcomings introduce increase data uncertainty. System-of-system interoperability shortcomings significantly decreases the SoS P_{kill}

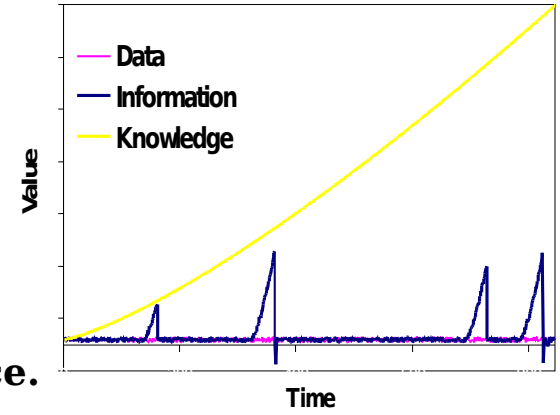
s determined in Single Integrated Air Picture Study (SIAP)

Data/Information/Knowledge Levels of Interoperability

Data : criticality and acquisition ease. associated uncertainty.

Information: situation dependent, "devalues" operationally with relevance.

Knowledge: increases over time and accumulates with Effect of incomplete knowledge transfer



- Communication Mechanism
  - Communication Bearer
    - Human
      - Voice
      - Telephone
      - Email
    - System (Machine)
      - JTIDS
      - JRE
      - JTRS
  - Message Structure
    - Human
      - English language syntax
    - System (Machine)
      - Link16 J-Message Set
- Context for information significance
- Semantics for understanding

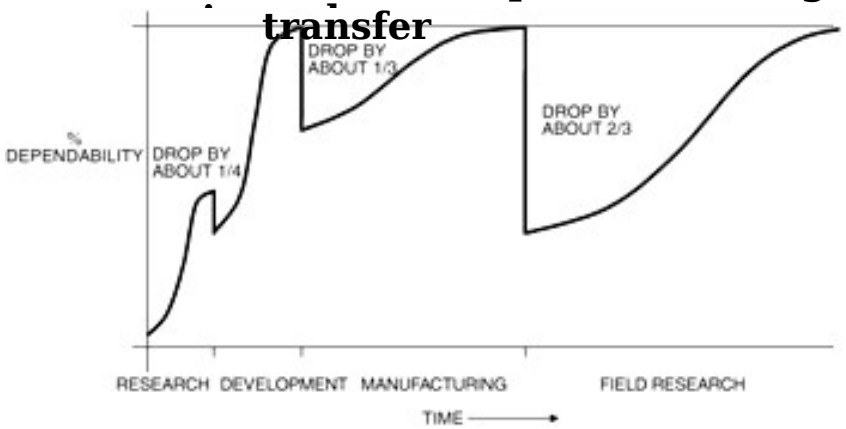
(Explicit : expressed as rules, codified.
Tacit : requires interpretation)

Data Transfer (Interconnected)

Information Transfer (Coordination)

Knowledge Transfer (Collaboration)

Increasing Interoperability



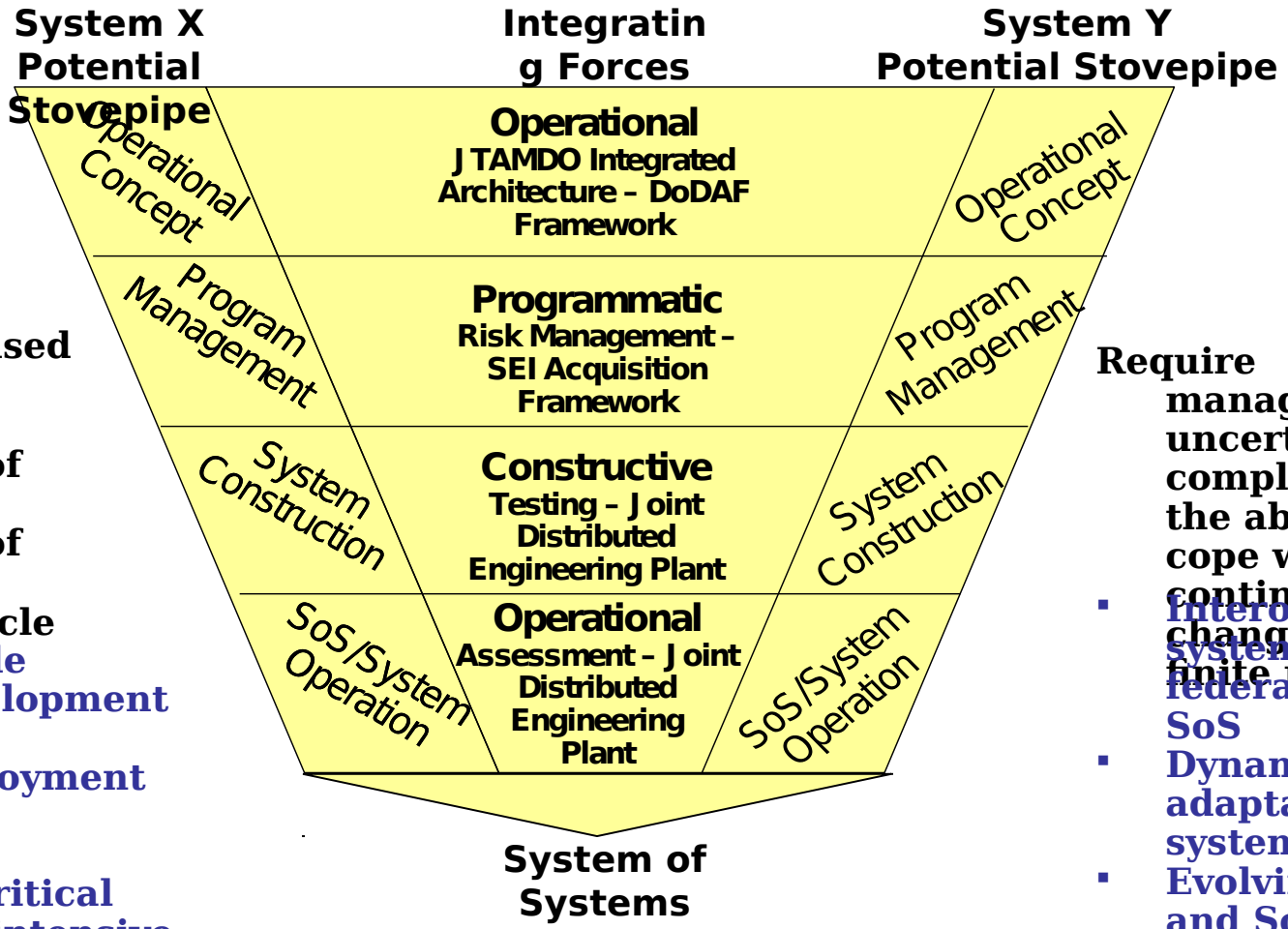
Interoperability Measures of Effectiveness

Information Exchange Effectiveness (IEE)	Fraction of information exchanges for which content and format, accuracy, and timeliness criteria are met.
Assured Information Integrity	Information exchange availability and accuracy of information exchanged.
Composite Warfare Picture (CWP)	Required for common situational awareness, and effective coordination of actions.

- Interoperability is not just about message formats or communication bandwidth!

- A majority of the warfighting interoperability challenge is due to the

Interoperability Life Cycle



Require increased agility to respond to:

- **Spectrum of Operations**
- **Spectrum of Alliances**
- **SoS Life-cycle challenges**
  - **Large scale**
  - **Long development cycle**
  - **Long deployment cycle**
  - **Real-time**
  - **Mission-critical**
  - **Software-intensive**

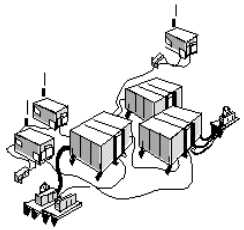
Require management of uncertainty and complexity, and the ability to cope with continuous change with finite resources.

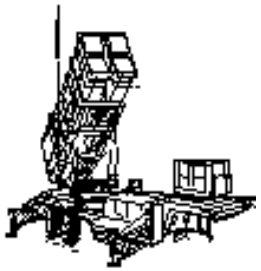
- **Interoperable systems federated as a SoS**
- **Dynamically adaptable systems**
- **Evolving system and SoS capabilities.**

Vital for <u>interoperability/design time knowledge transfer</u> to maintain a closed-loop from the requirement specification process to the operational assessment process.

What is Architecture?

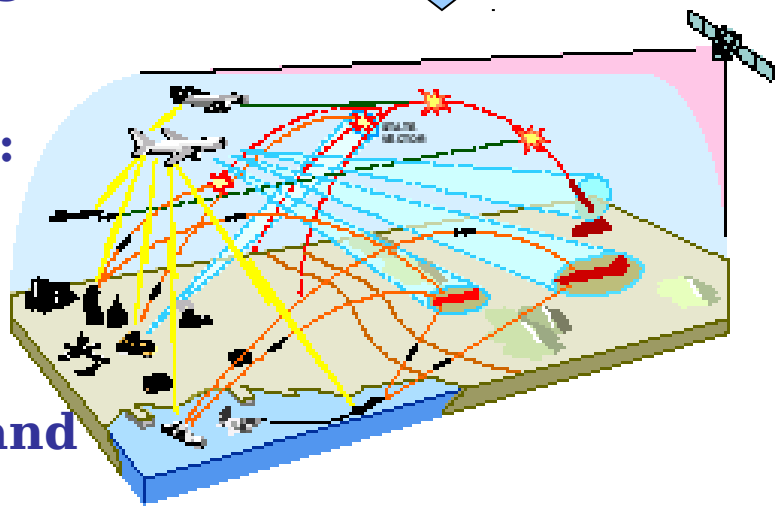
DoD Definition of Architecture :
"Structure of components, their relationships, and the principles and components governing their design and evolution over time" (DoD Architecture Framework).





Architecture details:

- **How systems and system-of-systems (SoS) are assembled from a set of heterogeneous autonomous collaborating warfighting building blocks to carry-out a set of operations.**
  - **Operational Activity and Interchange definition**
  - **Building block capabilities**
  - **Initially rules, later patterns which:**
    - **Guide composition**
    - **Define interactions**
    - **State mission dependencies on operational capabilities**
  - **Constraints on those composition and interactions**



What does Architecture Provide?

- **Architecture provides:**
  - **Structure and mechanisms for knowledge transfer**
    - **Mutually consistent orthogonal views or models of the problem and solution space**
    - **Common definitions, data, and frame of reference**
    - **Predictive capability to support operational planning and investment decisions**
  - **Performance assessment, interoperability, and control logic validation through Executable Architectures**
  - **A continuum with SoS/system design. The Operational Architecture is the first opportunity to engineer the SoS.**
    - **The Warfighting "Business" Model is a system or system-of-systems representation of warfighting operational activities**
      - **The WHAT and HOW of Warfighting activities**
        - **Logic and information transforms mapped to the UJTL**
      - **Independent of implementation**

Why develop Architectures? (Utility of Architecture)

- **Architectures are used for:**
  - **Resource planning and acquisition strategy**
    - **Support investment decisions as to evolve legacy systems or develop revolutionary new systems**
  - **System of systems definition**
    - **Operational concept**
    - **Interoperability analysis**
      - **Interface specification and control**
    - **Evaluation of behavior and performance**
    - **Identification of system duplications and gaps**
    - **Time-phased evolution**
    - **System development**
  - **Knowledge repository**

DOD Guidance

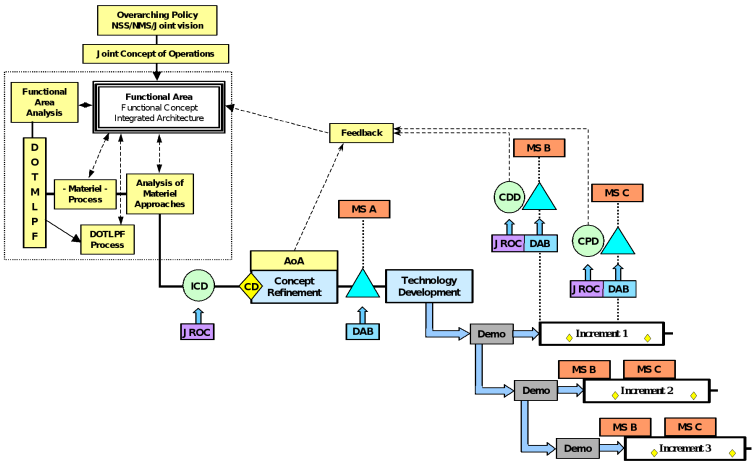
Department of Defense - DODI 5000.2

Assigns Joint Staff, USD(AT&L), and

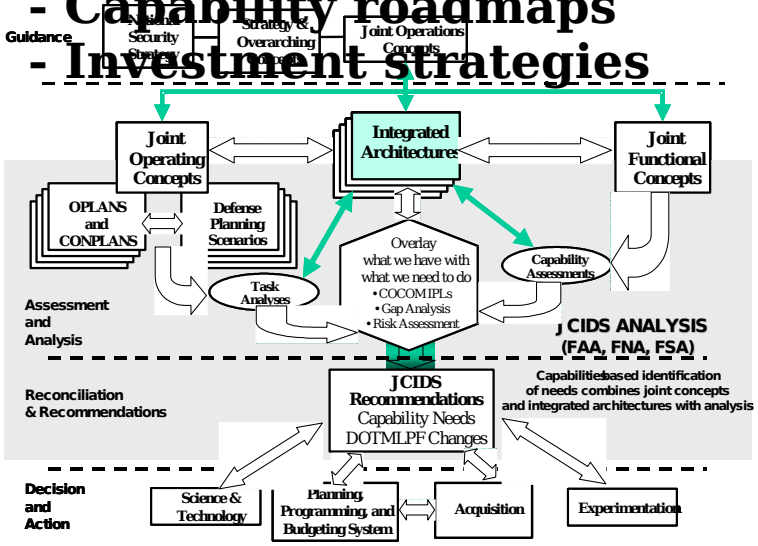
Service responsibilities for developing integrated architecture

Assigns USD(AT&L) responsibility to develop:

- **Integrated capability assessments**
- **Capability roadmaps**
- **Investment strategies**



Joint Capabilities Integration & Development System (JCIDS)

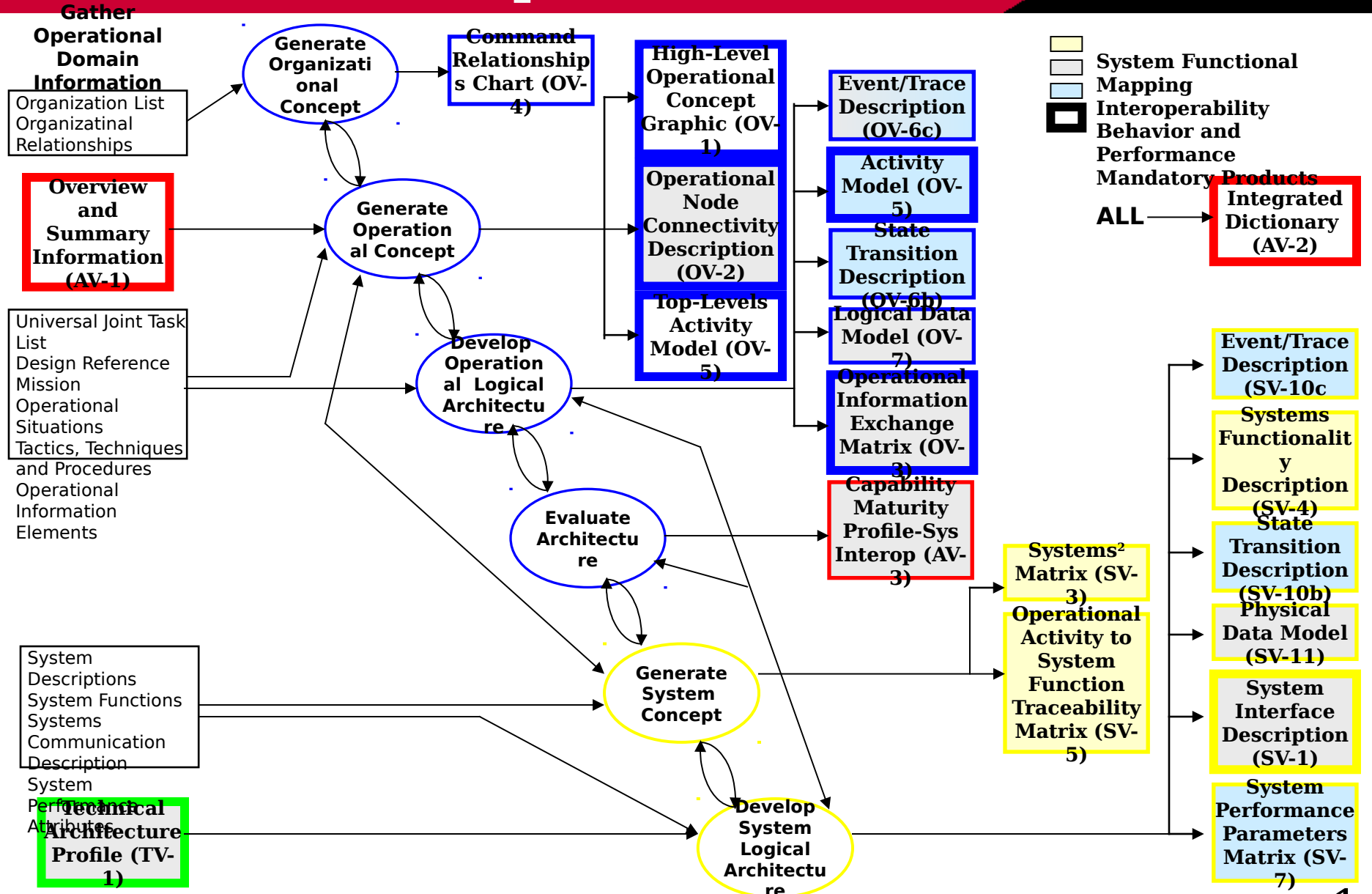


Joint Staff - CJCSI 3170.01c (Jun 2003)

Integrated architectures will provide the construct for analysis to identify:

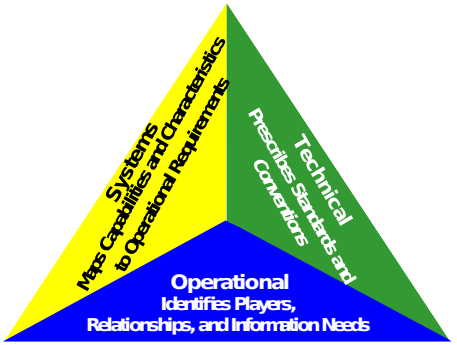
- **Capability and supportability shortfalls**
- **Alternatives for improving warfighting capabilities**

Example Architectural Development Process

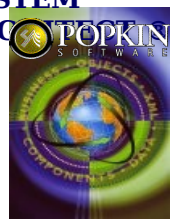


Architecture support for Analysis

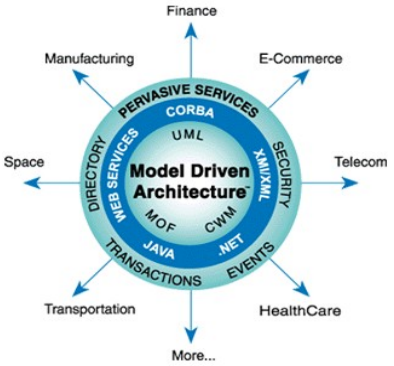
- **Architecture development support**
  - **Frameworks**
    - **There are 2 DoD Architectural Framework (DoDAF) compliant Architecture Analysis and Design approaches:**
      - **Structured Analysis (SA) using IDEF notation**
      - **Object Oriented Analysis (OO) using UML notation**
        - » **DoDAF, Jan '03, has come out in strong support of OO Operational Architectures.**
    - **Model Driven Architecture is a Standards-based technology based on UML-2 that is used to develop SoS through separate mutually consistent executable models of:**
      - » **Operational (business) structure and behavior**
      - » **Non-platform-specific System structure and behavior**
      - » **Platform-specific system implementation**
  - **Modeling tools**
    - **Commercial tools support the above frameworks.**
    - **DoD sponsored tools support domain-specific performance assessment and some aspects of interoperability directly interfaced to the architecture**



SYSTEM ARC



eXecutable



Analysis and Design Approach Comparison

Analysis and Design decomposes the problem space along specific axes to manage complexity, then composes the system (system of system) to meet the objectives. Several decomposition axes exist

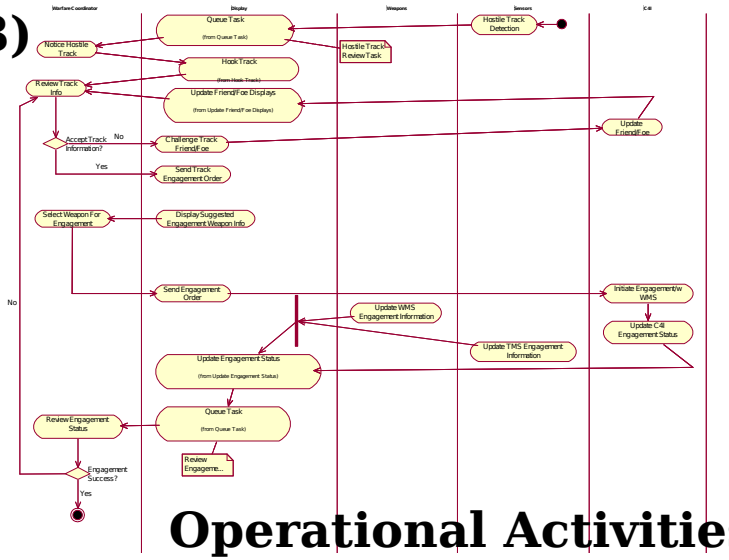
	Structured Analysis	Object-oriented Analysis
Primary motivation	Early approach to increase discipline in system engineering * Displace ad-hoc SE approaches	Build adaptable, maintainable systems. As systems evolve, functions tend to change, but objects remain unchanged. * Developed to address Structured Analysis limitations * OO Systems are inherently more adaptable
Decomposition approach	Function (behavior) and features (data) decomposed separately * Behavior and data loosely coupled leads to consistency maintenance challenges	Hierarchical real-world objects or concepts incorporating both data structure and behavior * Encapsulation of behavior and data increases cohesiveness and isolation. * Object interaction occurs only at defined interfaces. * Unplanned redundancy eliminated.
Composition approach	Combining data structure and functionalities together, e.g.. definition of flow of data and it's processing * Leads to early "how" to do focus, instead of "what" to do	Definition of object interaction * More natural mapping encourages early focus on interfaces, late focus on function implementation details
Task ordering	No explicit ordering of tasks according to criticality, tendency to focus on the straight forward tasks first to quickly obtain higher % complete * Longer, higher risk schedule. * Frequently poorer overall performance.	Focus on the hard parts first, skeletal systems executing critical functions. Shorter critical threads. * Fewer nasty surprises. * Improved performance of critical operations

Object-Oriented Analysis (OO) evolved from Structured Analysis(SA). OO is more structured than SA. OO can be converted to SA, when desired.

UML-2 Behavioral Operational Architecture Products

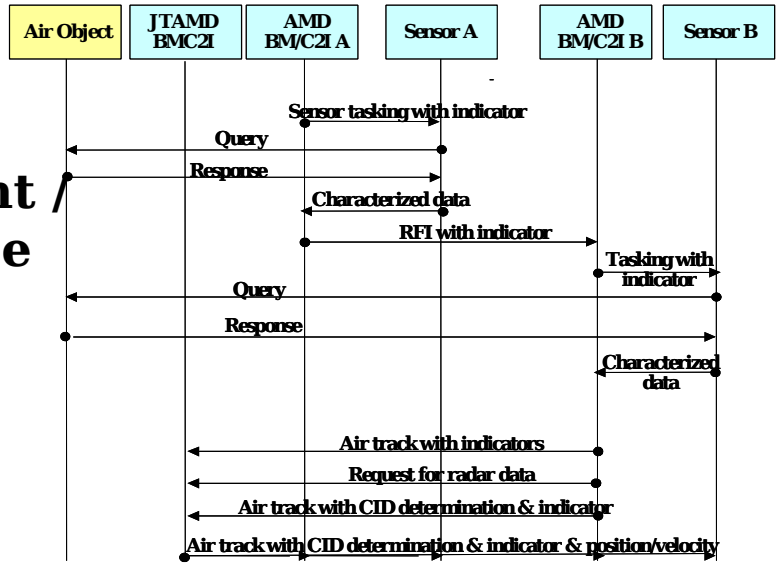
Information Exchange Detail (OV-3)

Critical (Interpretal Identifier/N of OV-2 Nee		Operational Elements Involved		Supported Operational		Description of Information	Communication Format		Performance Requirements		
		Information producing		UJTL	Task Description		Media	Message	Time-liness	Frequency	Size
		From	To								
N	1	Early Warning (IBS, AEGIS, J TAGS, PATRIOT)	Higher Command & Weapon System (THAAD, AEGIS, ABL, PATRIOT)	OP2.2.4	Provide COP	Target tracks (Common Operational Picture)	Data (TADIL J)	J 3.6 Space Track	<12 sec	Periodic, 1 track per object	225 bits
Y (8)	2	Early Warning (IBS, DSP, CRC/AOC, AEGIS, J TAGS, PATRIOT)	Weapon System (THAAD, AEGIS, ABL, PATRIOT)	OP2.2.5 OP2.4.2.4 OP.2.4.2.2 OP6.1.6	Generate and disseminate missile attack warnings	Early warning launch alert	Data (TADIL J)	J 3.0 Reference Point	xx sec	Event Driven, 1 per TBM	225 bits
Y (10)	3	Early Warning (IBS, DSP, CRC/AOC, AEGIS, J TAGS, PATRIOT)	Weapon System (THAAD, AEGIS, ABL, PATRIOT)	OP2.2.5 OP2.4.2.4 OP.2.4.2.2 OP6.1.6	Cue sensors and weapon systems	BM State Vector at Burnout, Radar Cue and Threat Data	Data (TADIL J)	J 3.6 Space Track + Covariance	xx sec	Event Driven, 1 per TBM after receipt from Space Based EW System	600 bits
Y (8)	4	Early Warning (IBS, AEGIS, J TAGS, PATRIOT)	Higher Command & Weapon System (THAAD, AEGIS, ABL, PATRIOT)	OP2.2.4	Provide missile data in COP	Target tracks (Common Operational Picture)	Data (TADIL J)	J 3.6 Space Track	xx msec	Periodic, 1 track per object	225 bits
Y (1)	5	Higher Command	Weapon System (THAAD, AEGIS, ABL, PATRIOT)	OP3.2.7	Select weapons to engage missiles: order of engagement	Target assignments	Data (TADIL J)	J 9.0 Command Message track number assignment	xx sec	Event driven, 1 message per threat to selected systems	75 bits

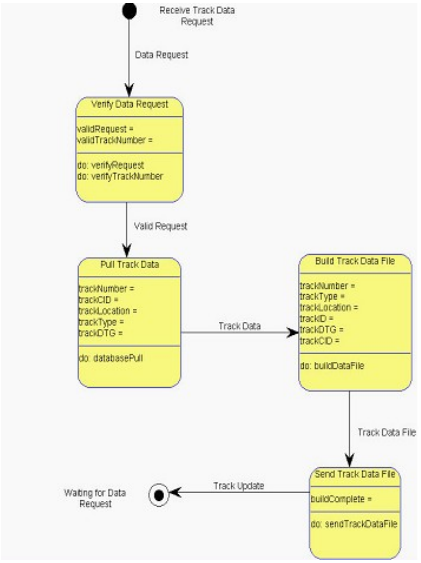


Operational Activities (OV

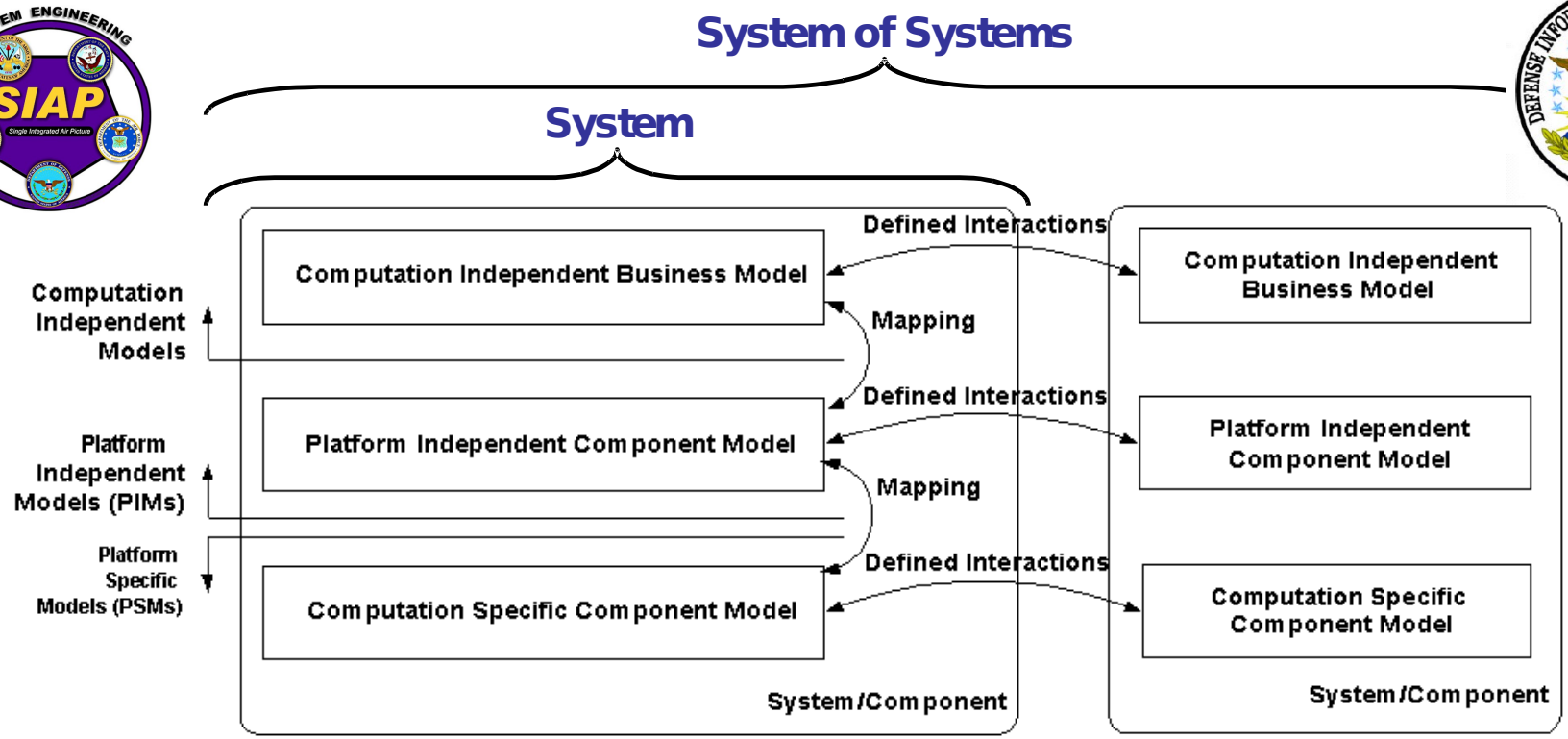
Op. Event / Trace (OV-6c)



Op. State Transition (OV-6b)



Conclusion/Futures: DoD Behavioral Models / Executable Architectures



- **DoD Architectural Framework and SystemC are being merging (at least in part) with OMG System Engineering Domain Specific Interest Group (SysEng DSIG).**